A selection of UT/LS H2O and O3 science issues

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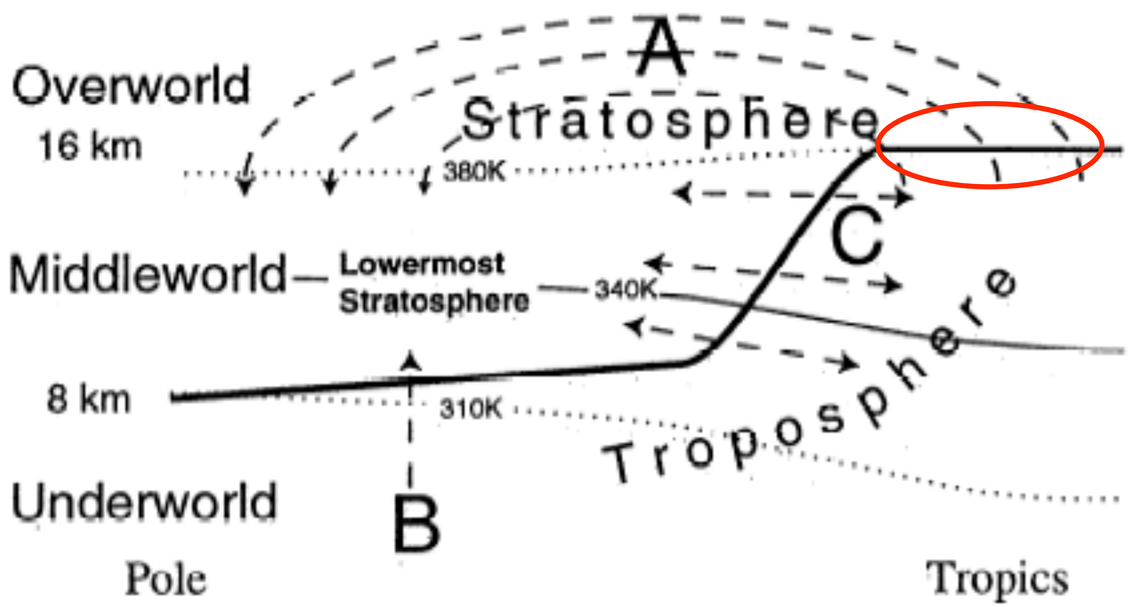
Issues

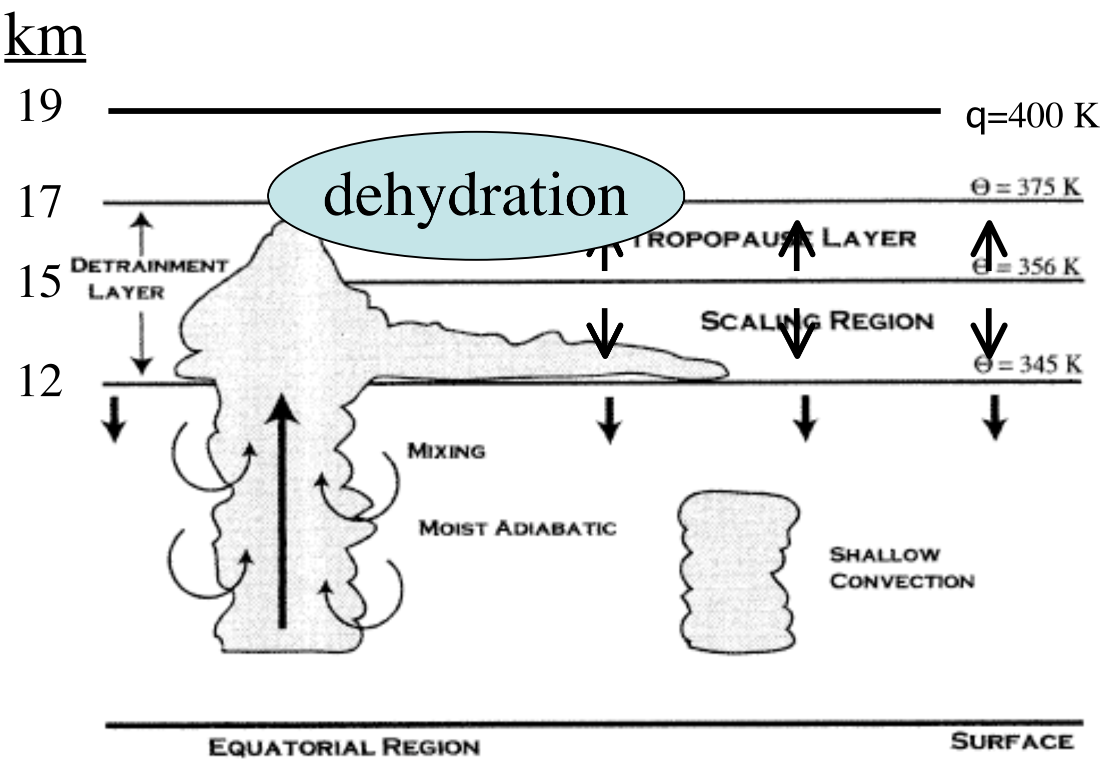
- Tropical Tropopause Layer processes
- Stratosphere-troposphere exchange of O_3 along isentropes
- Effects of convection on the extratropical lower stratosphere

Hoskins, B.J., Towards a PV-θ view of the general circulation, *Tellus*, *43AB*, 27-35, 1991.



UT/LS: 345-400 K

The TTL



Sherwood and Dessler, 2000; 2001

Folkins, 2002

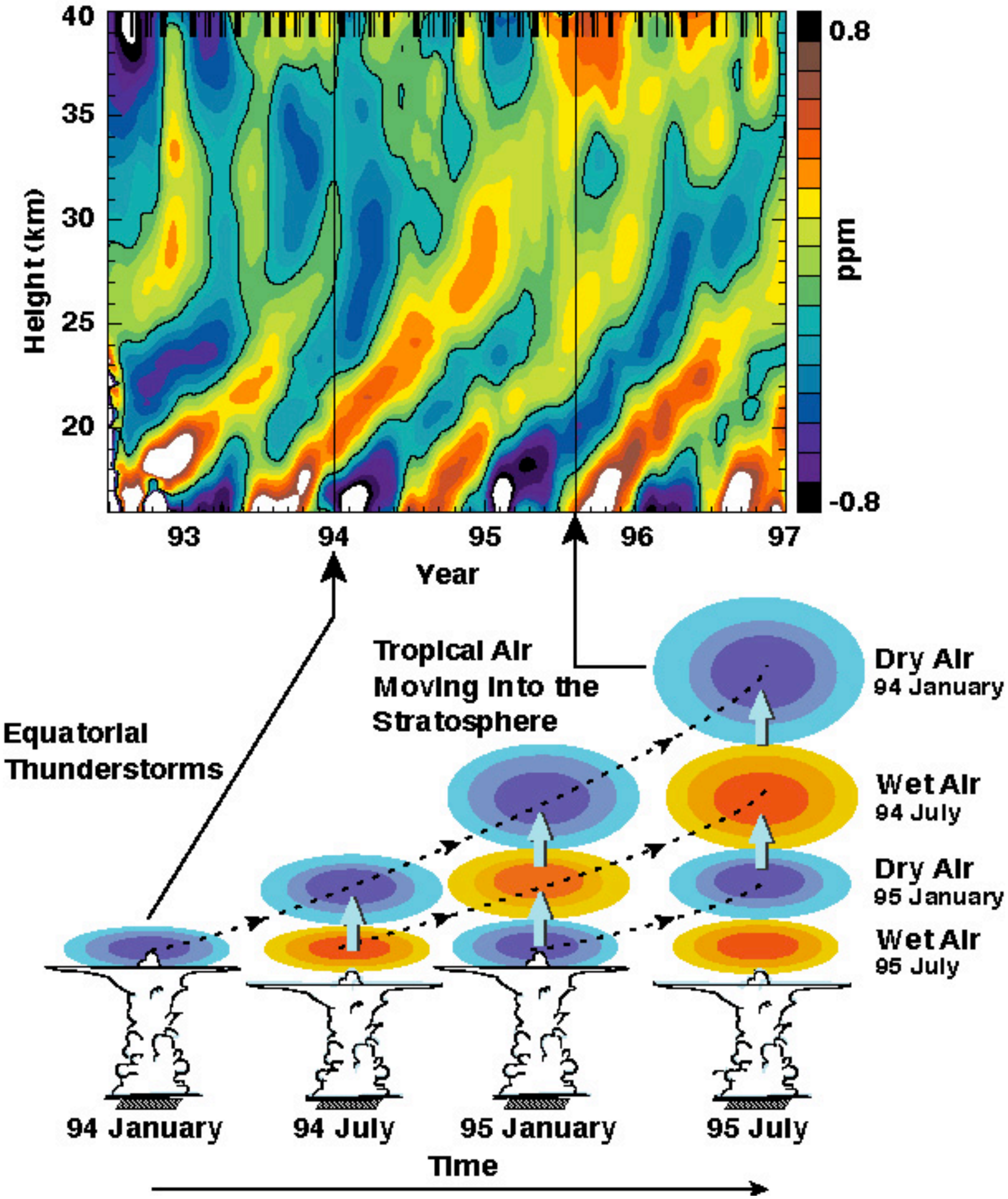
Gettelman and Forster, 2002

FIG. 14. A schematic overview of the structure of the tropical troposphere. Below 345 K, the temperature profile is maintained near moist adiabatic by shallow convection and by mixing on the sides of deep convective plumes. There is a rapid increase in deep convective outflow in the vicinity of 345 K. Between 345 and 356 K, deep convective outflow decreases with θ at a rate that is roughly proportional to the decrease in the CBL θ_e PDF. This has been labeled the scaling region. Between 356 K (~15.0 km) and 375 K (~16.6 km), the Hadley and Brewer–Dobson mass fluxes are of similar magnitude, and temperatures are under mixed tropospheric and stratospheric control. The entire outflow region from 345 to 375 K is called the detrainment layer.

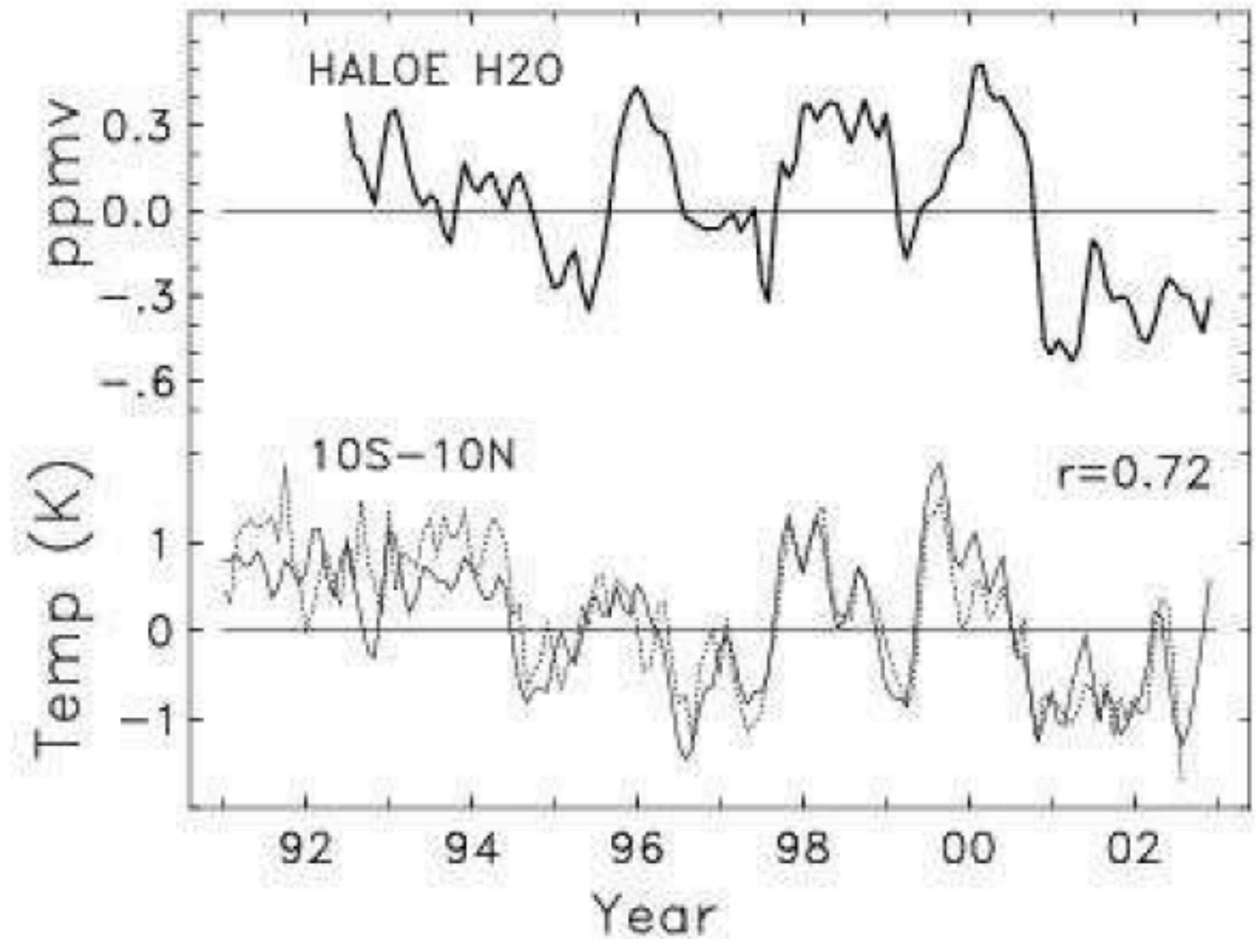
Folkins, **Origin of Lapse Rate Changes in the Upper Tropical Troposphere**, JAS, 59, p. 992, 2002

The "Tape Recorder"

Mote et al., An atmospheric tape recorder: The imprint of tropical tropopause temperatures on stratospheric water vapor, JGR, 1996.



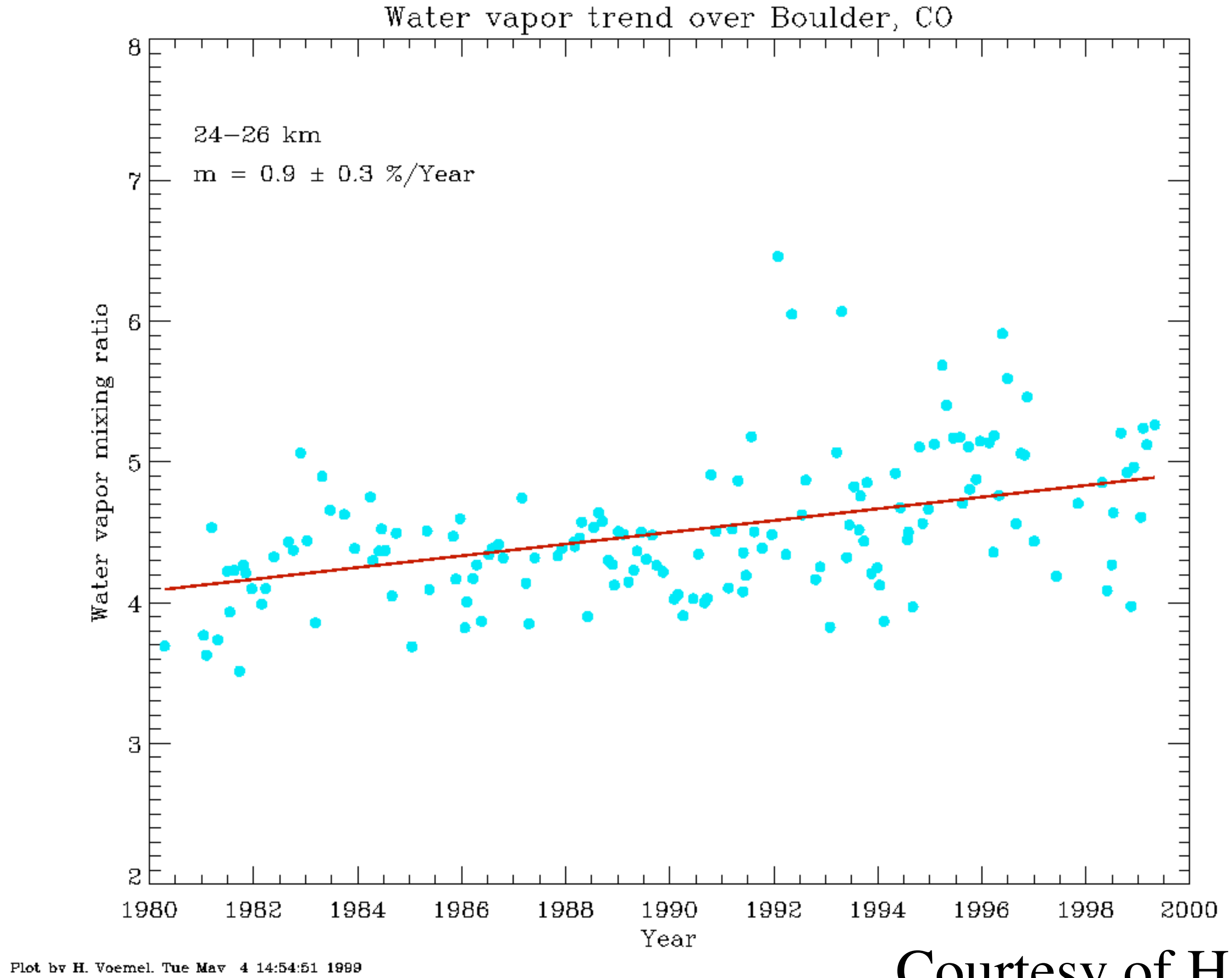
Source:
UARS brochure



Deseasonalized HALOE data

Randel et al., Interannual Changes of Stratospheric Water Vapor and Correlations With Tropical Tropopause Temperatures, JAS, in press, 2004.

Long-term trends in stratospheric humidity



Courtesy of H. Vömel

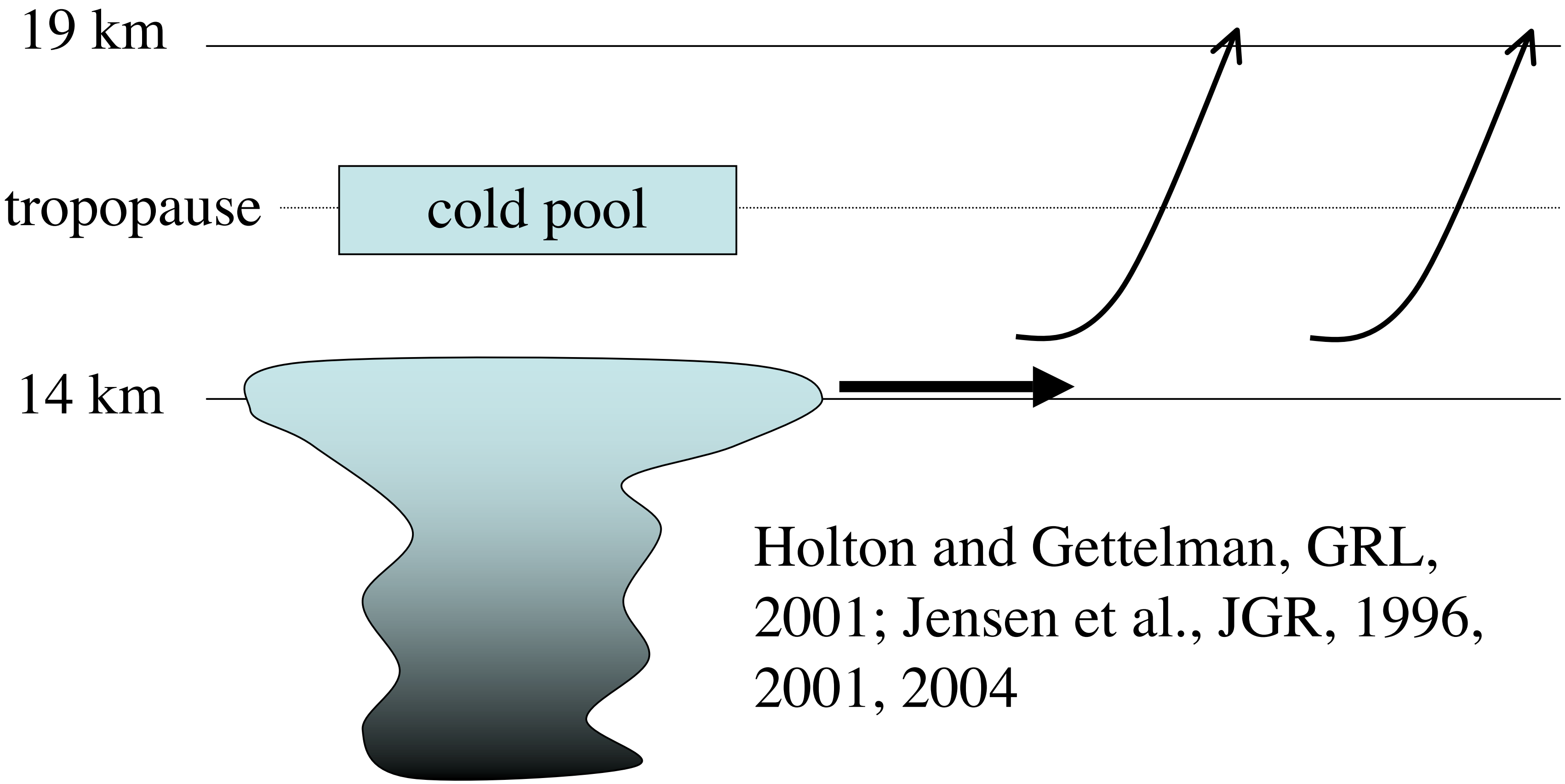
Causes of trends

- Increases in H_2O entering the stratosphere
  - 3.8 ppmv in the mid-1990s
  - Increased between 1985 and 1994 (ATMOS, Michelsen et al., JGR, 2000)
  - Decreased after 2000 (Randel et al., JAS, 2004)
- Increases in CH_4 entering the stratosphere
  - Is increasing; cannot explain the entire trend
- Increases in fraction of CH_4 oxidized
  - Transport changes (Rosenlof, J.Met.Soc.Jap., 2002)

Trends in H_2O entering the strat

- Microphysical control (Sherwood, Science, 2002)
- Changes in area of size of upwelling region (Rosenlof, J.Met.Soc.Jap., 2002)
- Changes in seasonal cycle of upwelling (Rosenlof, J.Met.Soc.Jap., 2002)

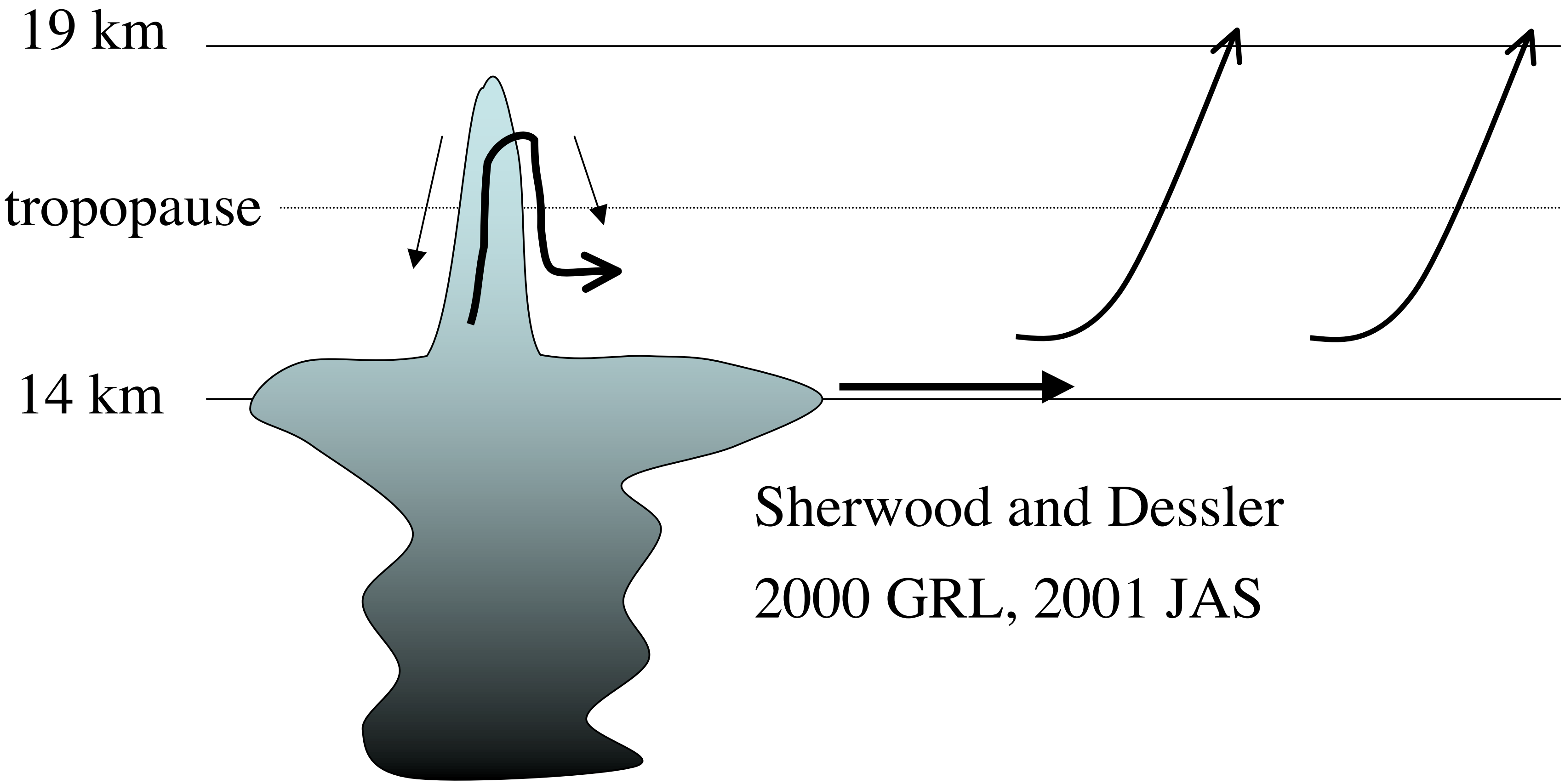
“Cold Trap” dehydration



Holton and Gettelman, GRL, 2001; Jensen et al., JGR, 1996, 2001, 2004

Based on pioneering work of Brewer, Danielsen, Newell

Convective Dehydration



Sherwood and Dessler

2000 GRL, 2001 JAS

Based on pioneering work of Brewer, Danielsen, Newell

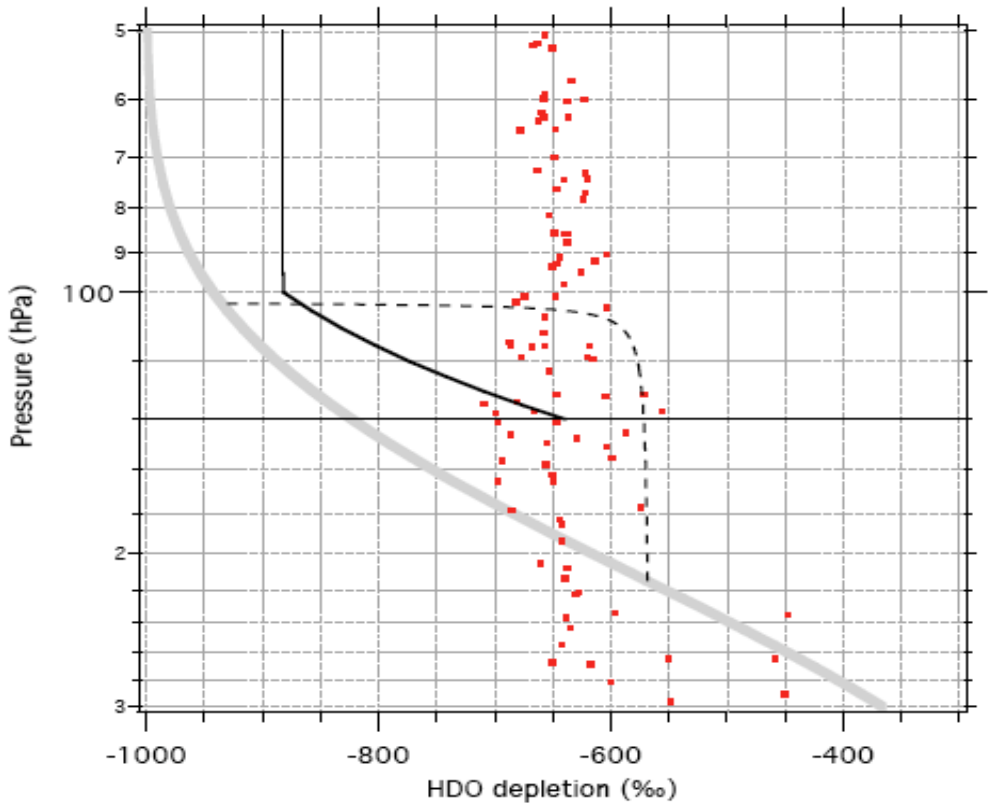
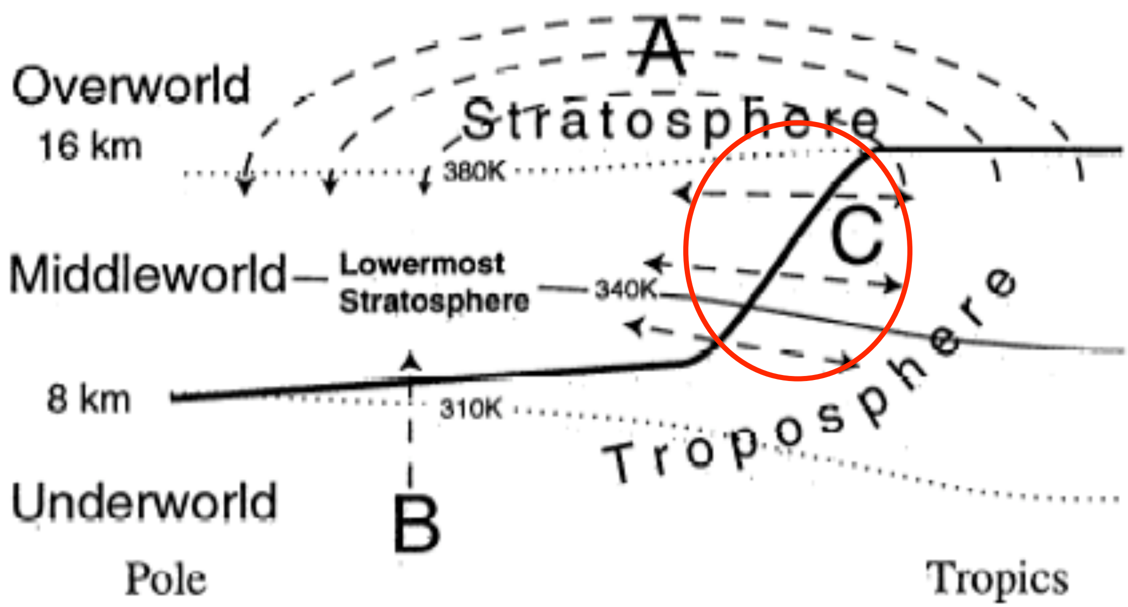


Fig. 1. HDO depletion δD (‰) in the vapor vs. altitude (hPa). The thick gray line is the Rayleigh curve, calculated for a parcel ascending from the surface pseudoadiabatically (see text). The dots are the ATMOS data in the TTL (Kuang et al., 2003), with the effects of methane oxidation removed. The dashed line is a mixing line between saturated parcels at 210 and 100 hPa, with initial HDO abundances set by the Rayleigh curve at these altitudes. The thin solid line is a calculation of TTL depletion as a result of in situ condensation, for air beginning with the observed depletion at the base of the TTL.

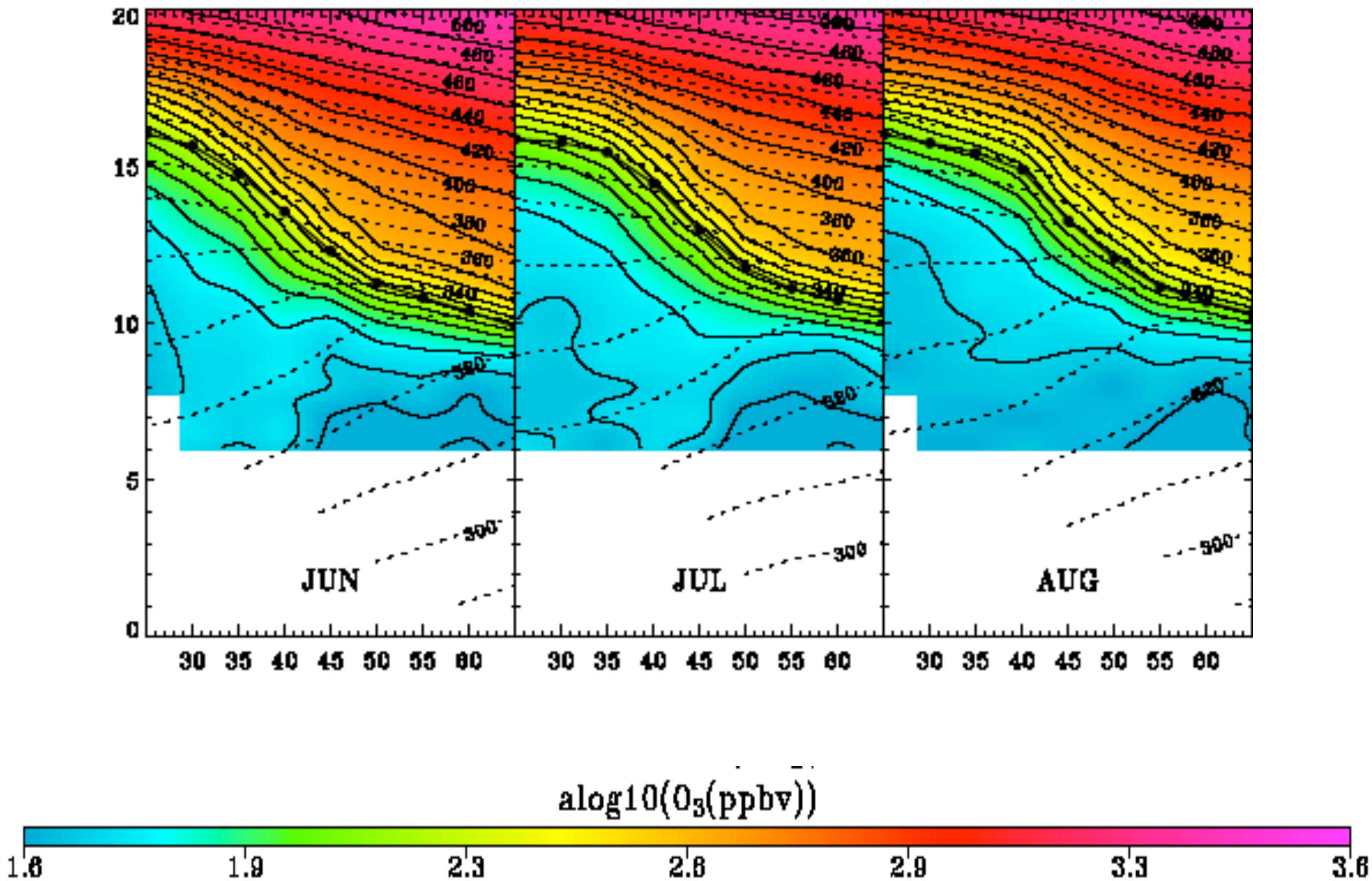
ATMOS data from Kuang et al., GRL, 2003

Dessler and Sherwood, A model of HDO in the tropical tropopause layer, ACP, 2003

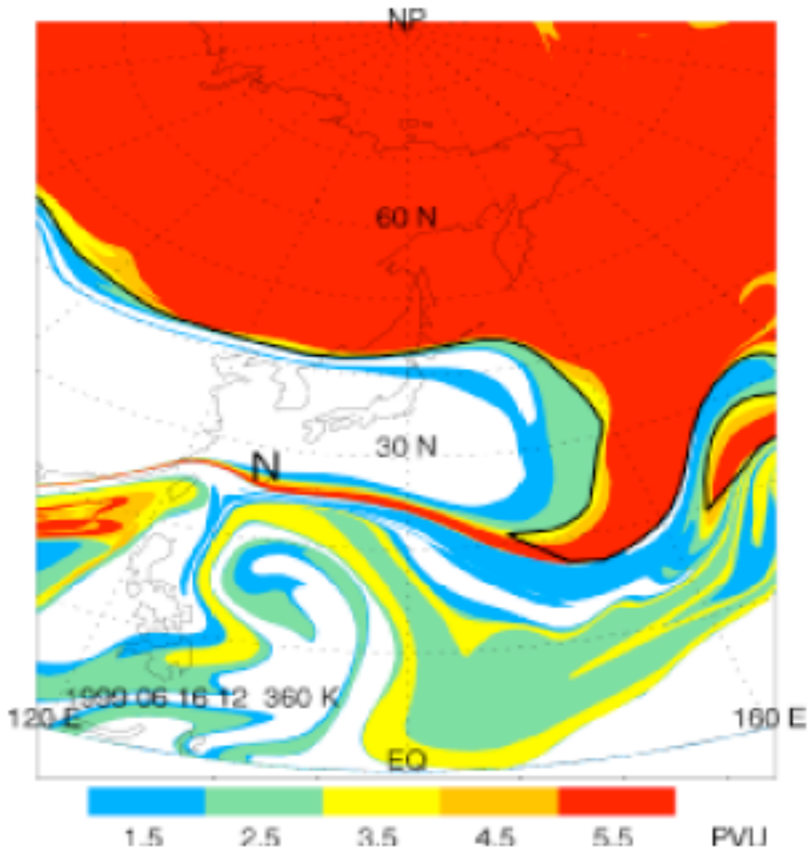
Hoskins, B.J., Towards a PV-θ view of the general circulation, *Tellus*, *43AB*, 27-35, 1991.



UT/LS: 345-400 K



Courtesy of P. Wang/LaRC



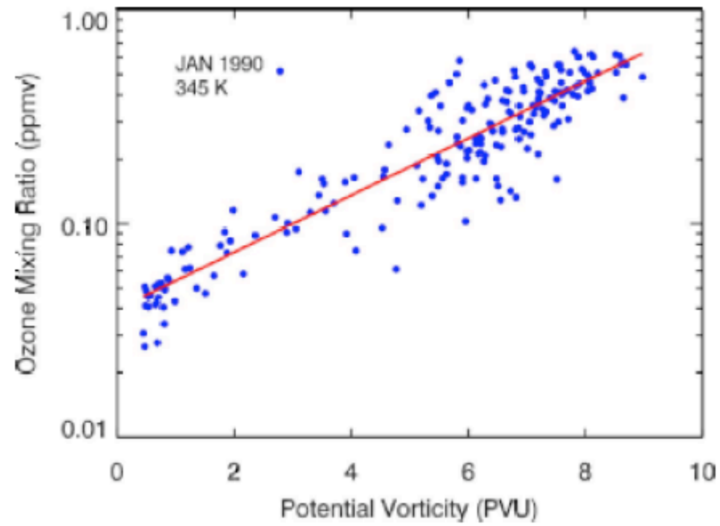
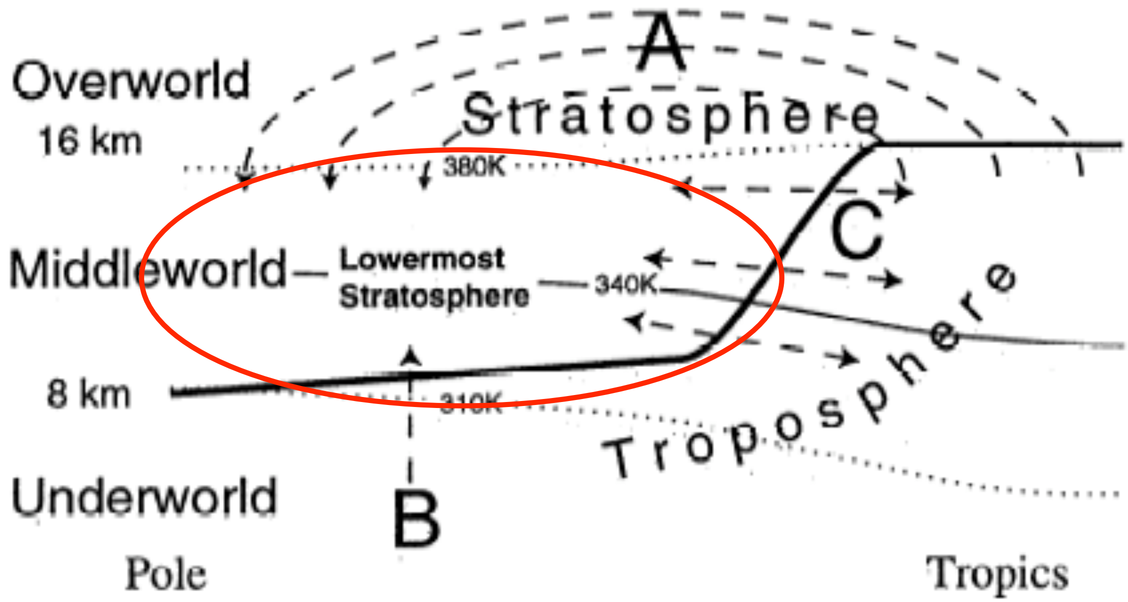


Figure 4. Scatter plot of PV and SAGE ozone mixing ratio at 345 K in the NH in January 1990. The least-square fit of PV and ln(O3) is represented by the red solid line.

Figure 2. PV field at 360 K on 16 June, 1999 at UTC 12 hr after 5-day Contour Advection calculations. The bold black lin represents the 3.5 PVU* tropopause. "N" represents the location of Naha.

See the Jing et al. poster

Hoskins, B.J., Towards a PV-θ view of the general circulation, *Tellus*, *43AB*, 27-35, 1991.



UT/LS: 345-400 K

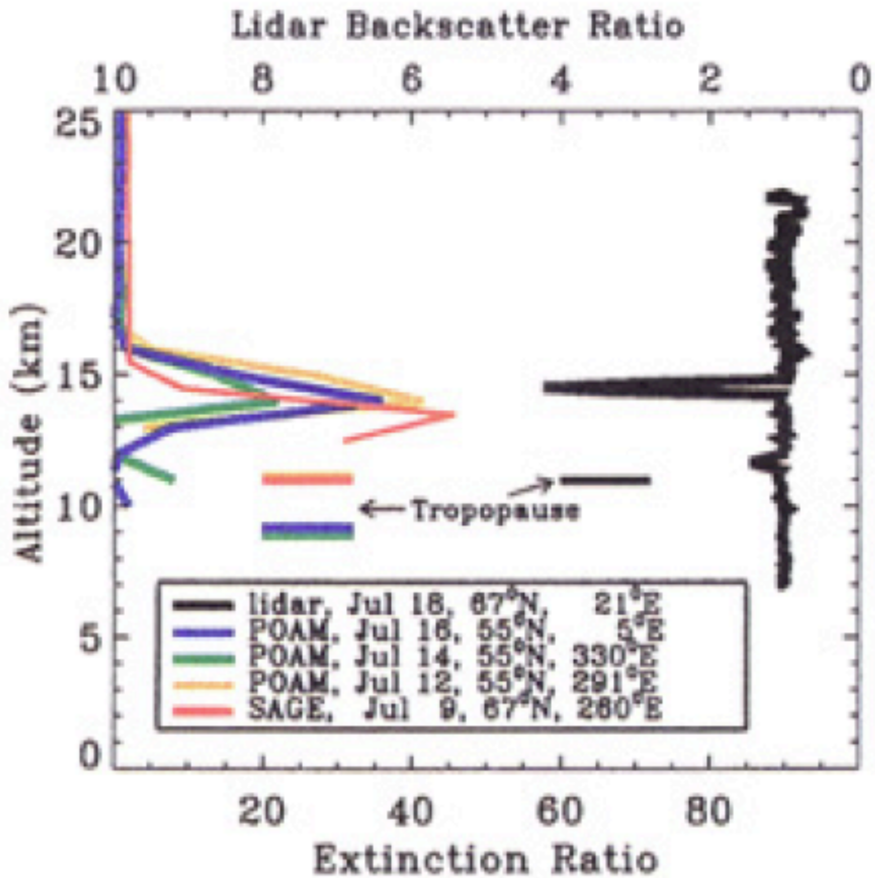
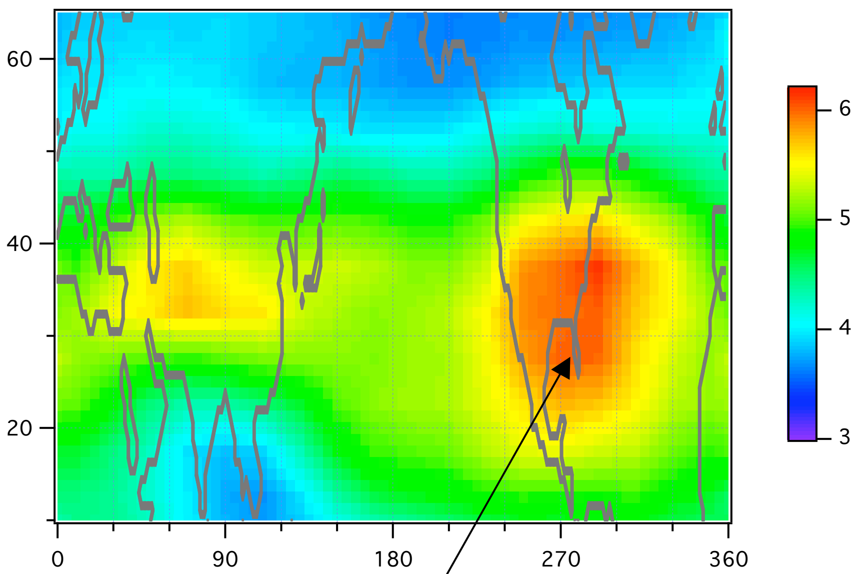
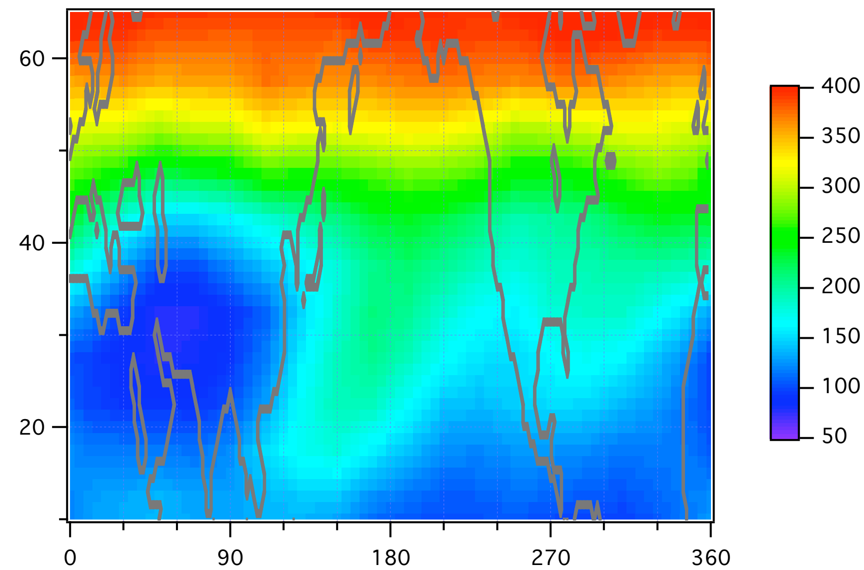


Figure 2. Selected aerosol extinction and backscatter ratio profiles showing stratospheric enhancements between July 9 and 18, 1998. Tropopause height collocated with each profile is shown by a matching color-coded horizontal bar.

Fromm et al., Observations of boreal forest fire smoke in the stratosphere by POAM III, SAGE II, and lidar in 1998, GRL, 2000.



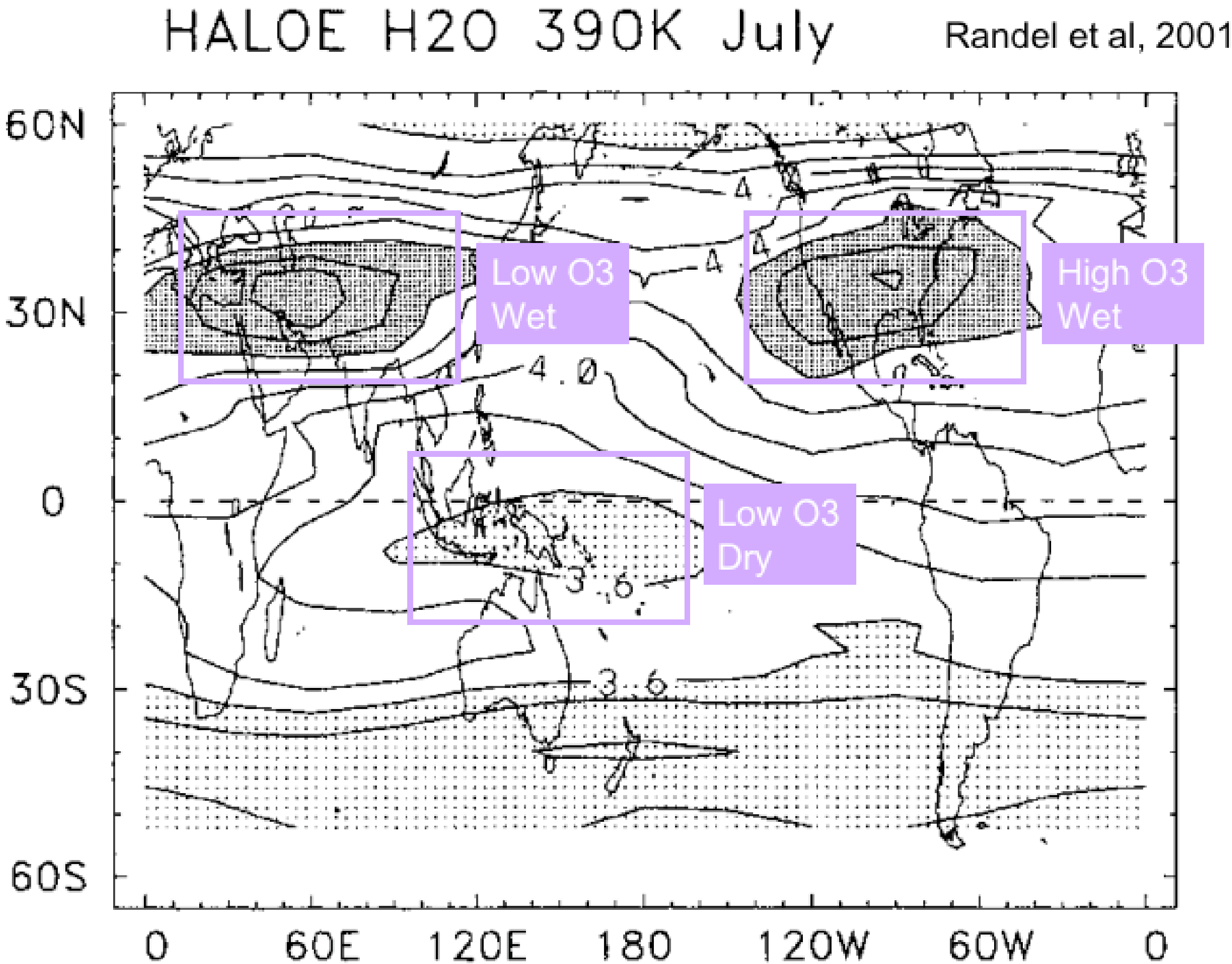
HALOE H2O 1993-99



HALOE O3 1993-99

500 ppbv
14 ppmv

July, 380 K



See T. Dunkerton's poster for more on the "tri-modal" structure

Convective tendency: $$\frac{\partial[X]}{\partial t} = -\frac{1}{\tau}\left(\boxed{[X]-[X]_C}\right)$$

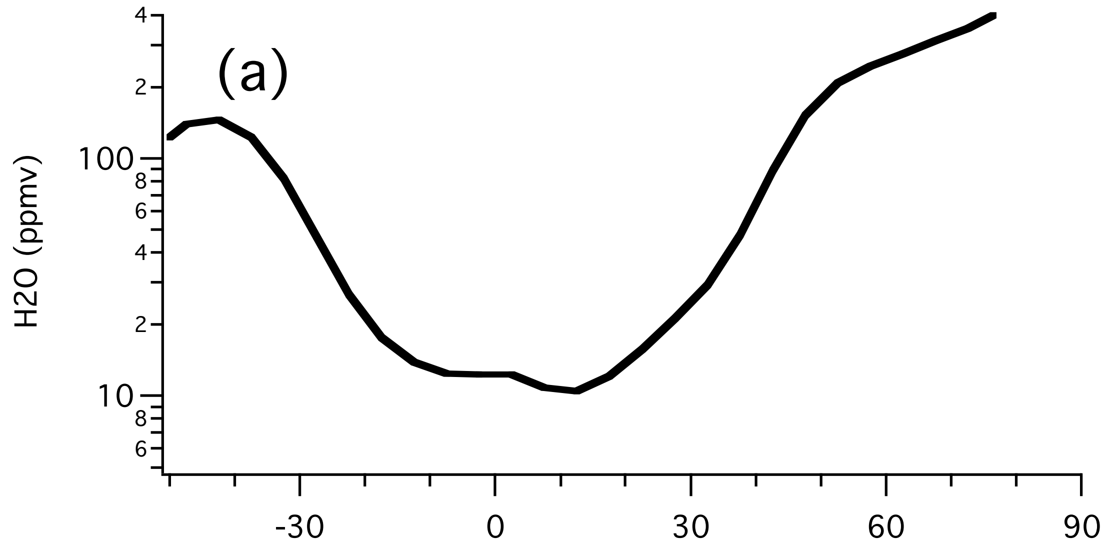
Convective
turnover
time scale

"convective leverage"

Function of convective mass
flux only, same for all
constituents

Species dependent

Zonal avg. saturation VMR @ 380 K for July 1992

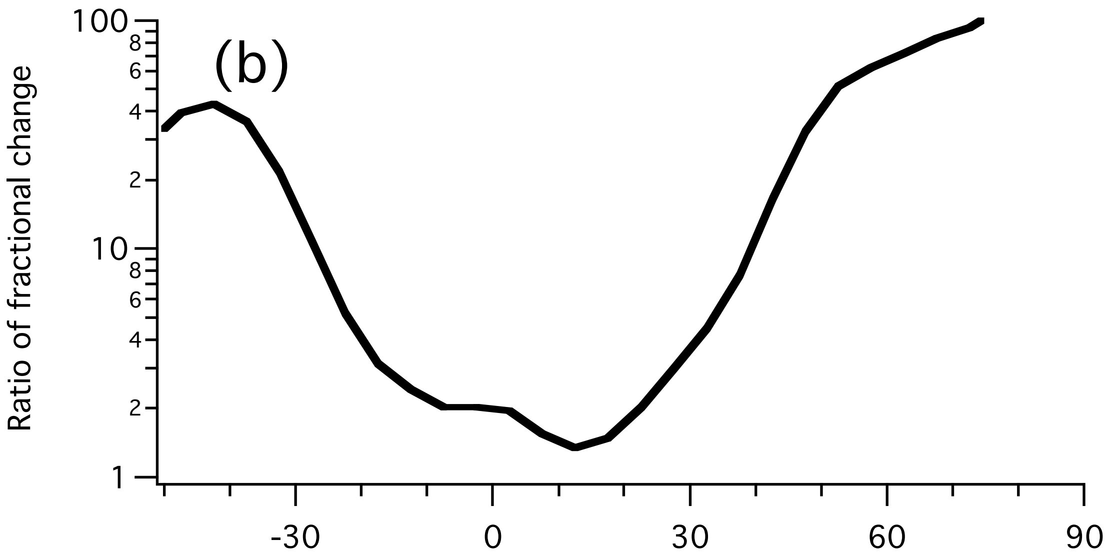


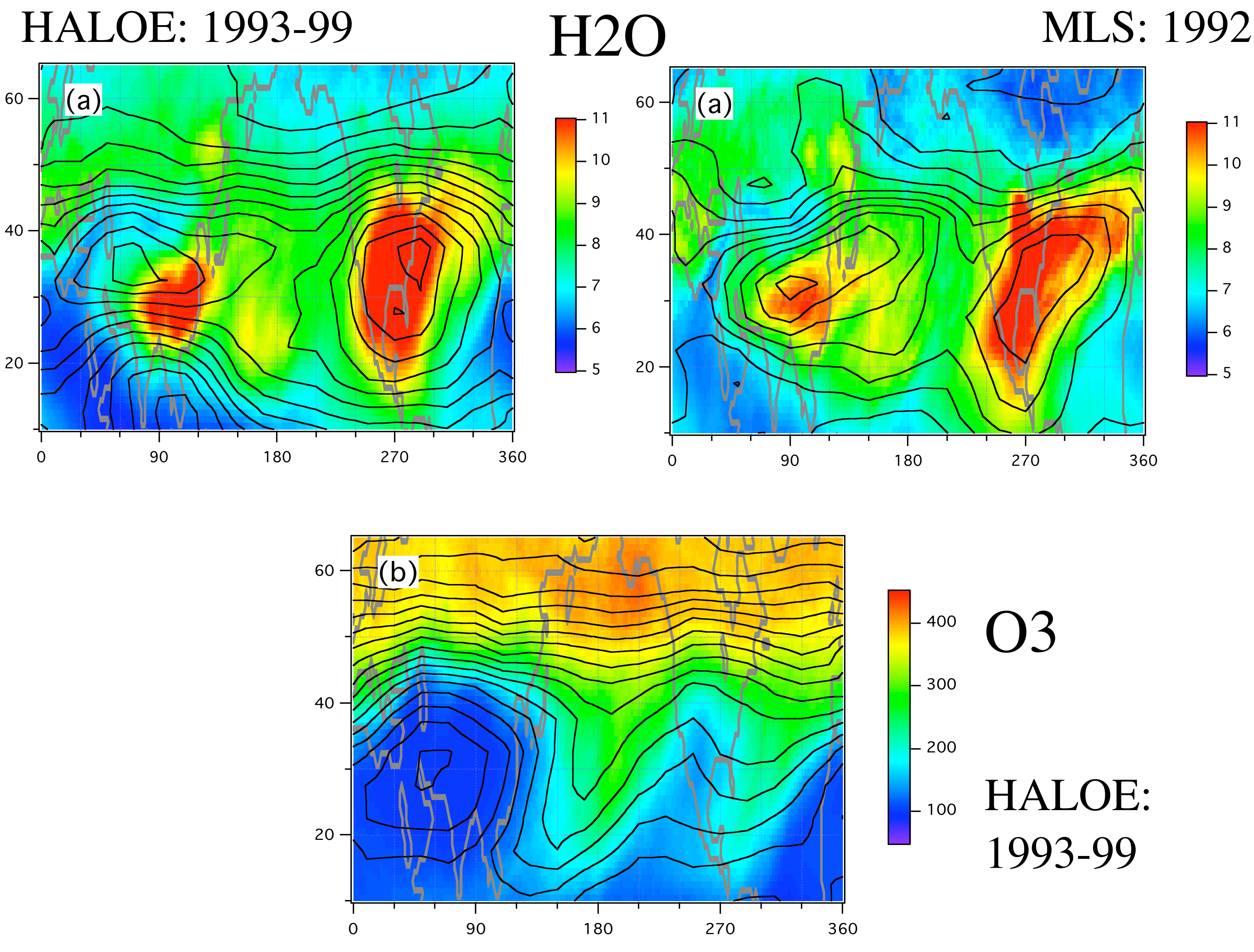
$$[H_2O]_C >> [H_2O]$$

$$\frac{\partial[X]}{\partial t} = -\frac{1}{\tau}\left(\boxed{[X]-[X]_C}\right)$$

$$\frac{\partial[\mathrm{X}]}{\partial \mathrm{t}} = -\frac{1}{\boldsymbol{\tau}}\left([\mathrm{X}]-[\mathrm{X}]_{\mathrm{C}}\right)$$

$$\left|\left(\frac{-\frac{1}{\boldsymbol{\tau}}\left([\mathrm{H_2O}]-[\mathrm{H_2O}]_c\right)}{[\mathrm{H_2O}]}\right)\Big/\left(\frac{-\frac{1}{\boldsymbol{\tau}}\left([\mathrm{O_3}]-[\mathrm{O_3}]_c\right)}{[\mathrm{O_3}]}\right)\right|$$





HALOE: 1993-99
H2O
MLS: 1992
(a)
(a)
(b)
O3
HALOE: 1993-99
60
40
20
0
90
180
270
360
11
10
9
8
7
6
5
400
300
200
100

Extratrop. Convection Summary

- LS H_2O up to 380 K is clearly affected by convection
- You don't need a lot of mass transport to have a big impact on LS H_2O
  - If the convection is occurring where the LS is warm
- LS O_3 is not tremendously affected by convection

UT/LS review

- Tropical tropopause layer
- Isentropic STE of O3
- Extratropical convection

I'd like to thank the SOSST steering group for the invitation to give this presentation. This work is supported by ACMAP and EOS/IDS grants to the Univ. of Maryland